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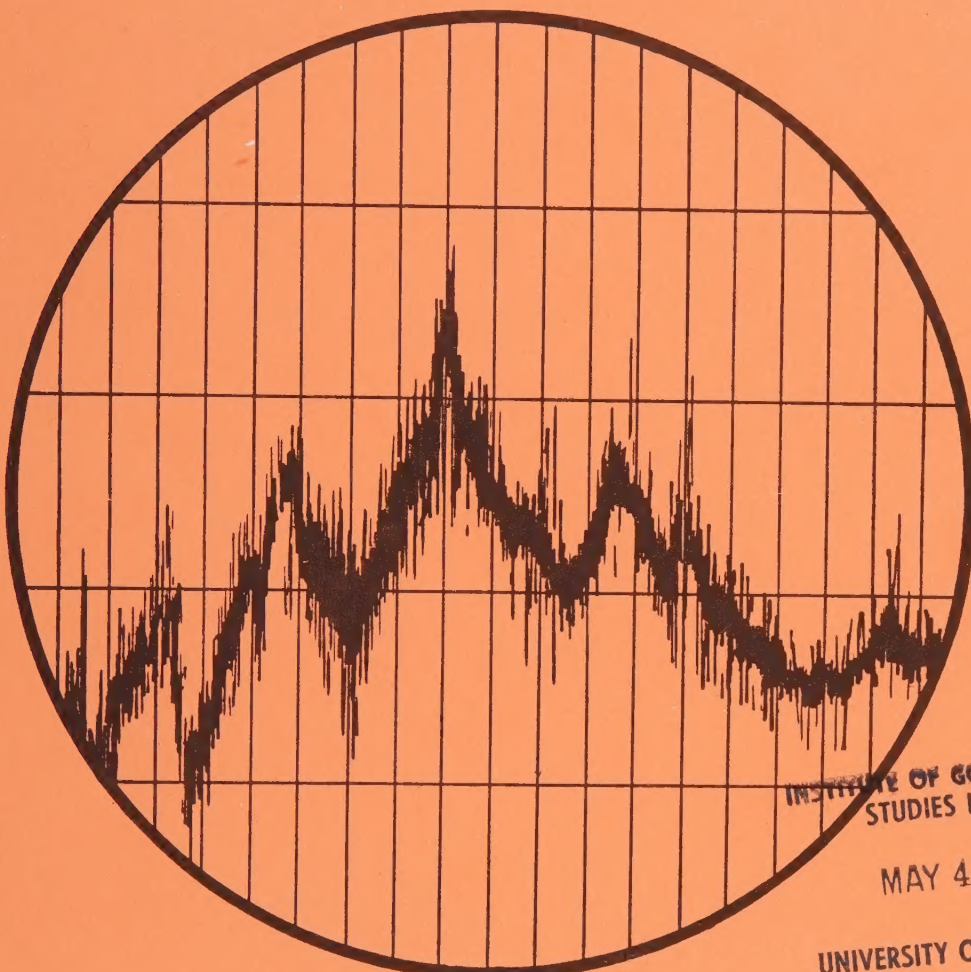
SEISMIC SAFETY



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AN ELEMENT OF THE GENERAL PLAN

City of Chula Vista, Calif.

87 01691

THE SEISMIC SAFETY ELEMENT

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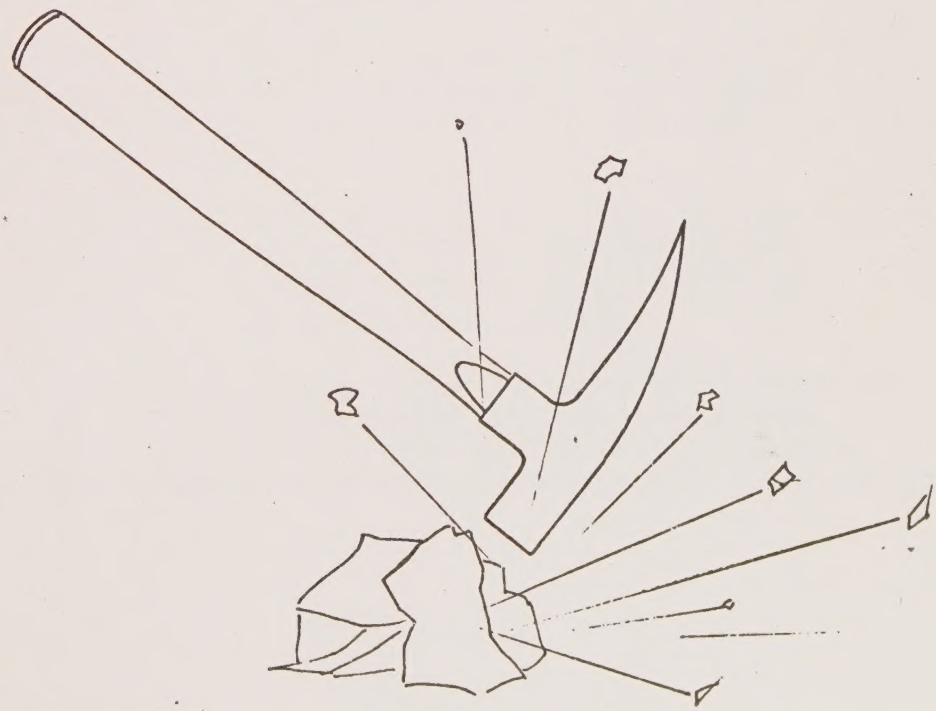

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SECTION I

BACKGROUND INFORMATION

for the

SEISMIC SAFETY ELEMENT

A. INTRODUCTION

The Circum-Pacific Seismic Belt; Purpose of the Seismic Safety Element; State Law

The Chula Vista Planning Area is situated within the Circum-Pacific Seismic Belt, a freeform strip of land and coastal waters which include the West Coasts of North and South America, all of Central America, much of the Caribbean, Japan, the South Pacific, and New Zealand. Within the Belt, which is composed of volcanoes, faults, oceanic rifts and trenches, and mountains, 80% of the planet's earthquakes occur.

Earthquakes usually result from the movement of huge plates of the earth's crust, and are therefore not preventable. Notwithstanding this factor, a program based upon the identification and appraisal of geologic hazards and the careful siting of urban structures and facilities can reduce catastrophic effects of diastrophism.

The Seismic Safety Element is a companion plan of the Safety Element, and its purpose is the promotion of public safety from geologic hazards. As a general plan the element is a framework of policy and requires precise and specific plans for implementation. The latter will be oriented towards guiding Chula Vista's future urbanization and revitalization along lines which are consistent with the accepted practices of seismic safety. The said precise and specific plans will also address the need to provide effective emergency and disaster services in the event of earthquake and related geologic activity.

The State Planning and Zoning Law of the Government Code, under Section 65302, subsection (f) now requires each city and county within the State of California to prepare and adopt a Seismic Safety Element, and to incorporate the said element into its general plan. The aforementioned statutory provisions read:

> "65302. The general plan shall consist of a statement of development policies and shall include a diagram or diagrams and text setting forth objectives, principles, standards, and plan proposals. The plan shall include the following elements:
>
> "(f) A seismic safety element consisting of an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to effects of seismically induced wafes such as tsunamis and seiches.
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> The seismic safety element shall also include an appraisal of mudslides, landslides, and slope stability as necessary geologic hazards that must be considered simultaneously with other hazards such as possible surface ruptures from faulting, ground shaking, ground failure and seismically induced waves."

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B. IDENTIFICATION AND APPRAISAL OF LOCAL GEOLOGIC HAZARDS

The City of Chula Vista's planning area is traversed by a total of five faults, including two potentially active faults, the Sweetwater and La Nacion; and three inferred faults, the Otay River Valley Fault, the Telegraph Canyon Fault, and the San Diego Bay-Tijuana Fault.

There is considerable speculation among published professionals concerning the possibility that the latter faults, in fact, may be a portion of the larger more tectonically active Newport-Inglewood-Rose Canyon Fault System. Actually, there is little agreement on any issue involving these faults, including their activity.

Each of the aforementioned faults is addressed individually below. The information contained in this section is based upon extensive research of existing information sources, and it should be taken into consideration in the development of policy recommendations.

LA NACION FAULT

The La Nacion Fault is a moderate to high angle normal fault, striking north roughly parallel to the coastline. The fault may, or may not, be continuous, and recent investigation indicates that the system may be composed of four individual faults.

Recent trenching and boring tests indicate that 200-300 feet of movement has occurred along this fault during the quaternary* period, and that movement of a few feet has taken place during holocene times in at least two locations. These contentions are supported by Carbon-14 datings which set the maximum date of offset at 10,980, plus or minus 190 years, before the present.

McEwen and Pinckney, in their study entitled Seismic Risk in San Diego, indicate that the maximum credible event that can be expected along this fault system would be in the range of a Richter magnitude of 6.8 with an associated acceleration to 4/10th of one gravity force (G).

Woodward-Gizienski studies indicate that this fault should be regarded as active, and that a 250 foot wide preliminary planning fault zone be established. This is based upon investigations which indicate the soil conditions in the area are relatively unstable and not amenable to utilization as sites for permanent structures due to the high level of risk associated with ground shaking in this area. In late 1973, William Krooskos & Associates noted that a Carbon-14 analysis indicated that the fault was inactive, and that the

*The geologic terms employed in the text of this element are consisely defined in the glossary, which commences at page 18. Please also see the Geologic Time Scale on the Plan Diagram.

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most recent activity should be set at 13,373 years, plus or minus 225 years, before the present. They further requested that the City reconsider its contention that the fault should be considered as active. For purposes of the City of Chula Vista's Seismic Safety Element the La Nacion Fault will be considered to be potentially active.

However, the facts remain that epicenter data and offsetting of late quaternary or possibly holocene strata justify the potentially active classification of the planning area's five faults. In addition, the proximity of these faults to presently urbanized areas and areas of expansion indicate their critical importance. In light of the overwhelming amount of information indicating that the fault should be considered as potentially active, it is recommended that this designation be retained and that the requirement cited later be applied to development taking place in the vicinity of this fault system.

SWEETWATER FAULT

The Sweetwater Fault is located parallel to the La Nacion Fault for at least 15 kilometers and varies in distance from 1 to 3-1/8 kilometers to the west of La Nacion. It strikes north in the vicinity of the Sweetwater Valley and dips from 60° to 70° to the west.

The pliocene San Diego Formation is well exposed east of the Sweetwater Fault, while pleistocene terrace materials are evidenced to the west. Two kilometers north of the Sweetwater Valley, the fault offsets late pleistocene materials by at least 35 meters.

This fault could also be considered to be a southern extension of the Newport-Inglewood-Rose Canyon Fault and a part of the previously mentioned fault system, including La Nacion.

Abatement procedures will be of particular importance in this area due to the fact that much of it is urbanized at the present time.

SAN DIEGO BAY-TIJUANA FAULT

It appears as though the San Diego Coastal Area is a zone of moderate seismic risk within a region of high risk. However, recent evaluations of San Diego's earthquake hazard by the County Environmental Development Agency suggests that perhaps a little less complacency should exist. The continental shelf off the San Diego Coast is broken by numerous large faults. The evidence for these faults is based upon bathymetric topography and the plotting of epicenters. It appears as though the extreme western portion of the coastal plane is actually a part of the vaulted continental borderland.

Further, there appears to be a zone of faults extending from San Ysidro through San Diego and Mission Bay into Rose Canyon. Although these faults do not appear to have been recently active, the possibility of movement should be considered. It has been suggested that the faults in Rose Canyon and the Bay Areas continue north and offshore to connect with the Newport-Inglewood Fault. It has also been suggested that this zone may also be connected with the active San Miguel Fault in Baja California.

Wygand Research indicates that this system may also be traversed and offset by the Otay Valley and Telegraph Canyon Faults which will be discussed later. He further indicates that the quiescence experienced in this area may be explained by the locked nature of the fault zone and the existence of these traverse faults. Port District studies indicate that in 1964, three earthquakes occurred with a recorded magnitude of 3.5 on the Richter Scale, with epicenters near the southeast bend of the now existing Coronado Bridge. Activity of this nature in the middle of the bay appears to substantiate the claims of Wygand and justifies further investigation of this claim.

TELEGRAPH CANYON FAULT

In 1967, the Lockheed Company conducted a geological survey of the San Diego Bay and reported its results in Lockheed Report #20867. This report, in part, indicates that an apparent east-west trending fault intersects the bedrock surface immediately north of cross section E-Prime-E. (See attached Figure 1) The fault appears to offset the bedrock surface and basel alluvial deposits with 20-25 feet of material having been deposited since the last movement. According to the displacement of the bedrock surface shown on Sections I-I Prime, J-J Prime, and K-K Prime, the south side has moved downward approximately 6 feet relative to the north side, and accompanying horizontal displacement of about 2/10 mile with the south side moving east relative to the north side. The previously noted displacement was approximated by the offset of the channel walls.

The fault does not appear to traverse the entire area as it is not picked up on cross sections H-H Prime or G-G Prime. Its continuation to the west beyond the subject site is unknown, but it is assumed that it continues beyond the Silver Strand into the Pacific Ocean.

OTAY VALLEY FAULT

The Otay Valley is an inferred normal fault of small displacement and was first referred to by George B. Cleveland in Special Report #64 of the California Division of Mines and Geology entitled Geology of the Otay Bentonite Deposits in San Diego County, California.

This fault is believed beneath the alluvian of the Otay Valley. Cleveland bases his suspicions upon the discovery of the extensive outcrops of the Swietzer formation on the south side of the valley, and the relative scarcity of outcroppings of the formation on the north side of the valley. In addition, he observed that the difference in the elevation of the thickest clay bed, which occupies the same stratographic location on both sides of the valley, varies from 20-25 feet.

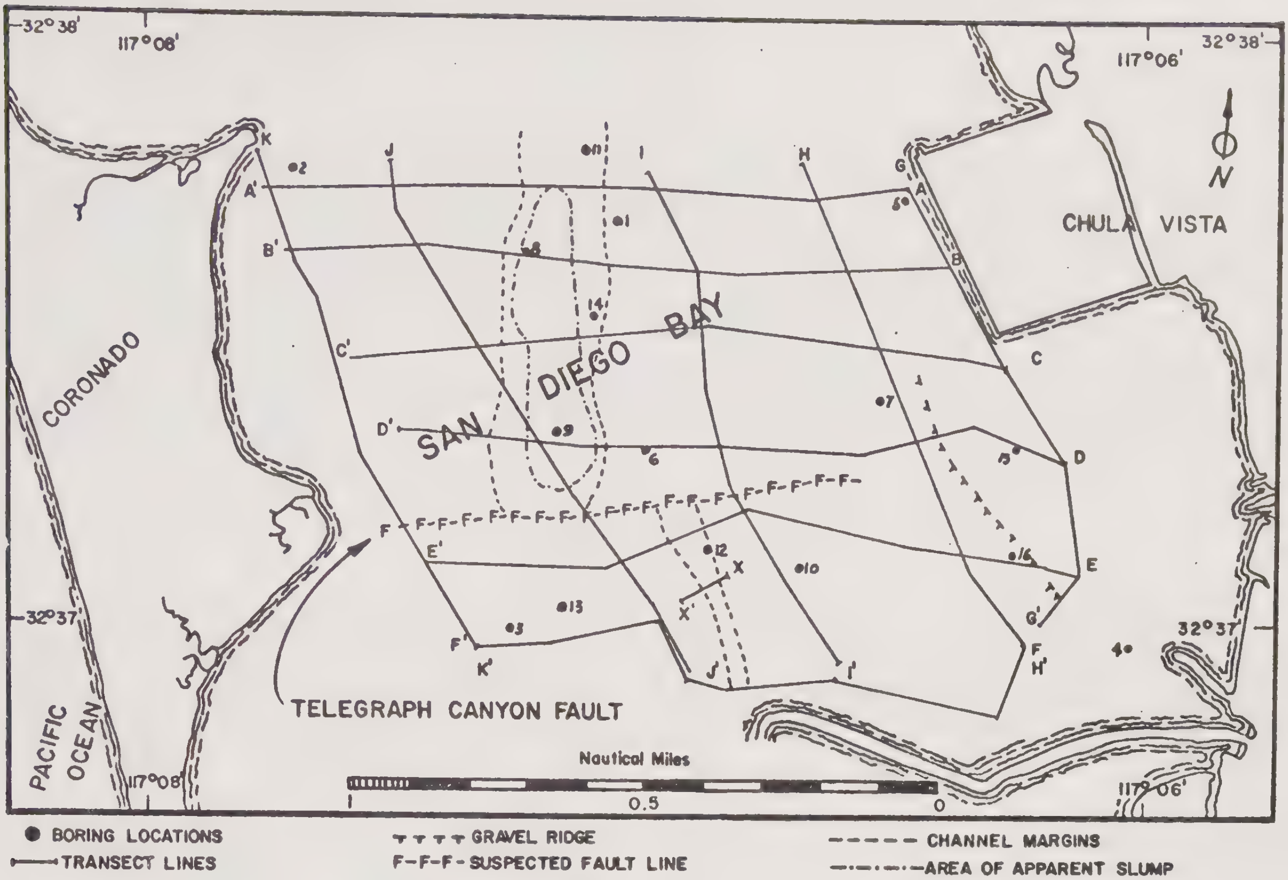

FIGURE I.

LOCKHEED BASE SURVEY MAP
OF THE TELEGRAPH CANYON FAULT

GROUND FAILURE

LANDSLIDES

Very little information has been compiled concerning landslides in the San Diego Region. Krooskos & Associates indicate that the reasons for this are: (1) only recently has development begun to occur in the previously remote areas containing slide evidence. This was due to the fact that most development occurred to the west on a relatively trouble-free marine terrace. (2) Most larger slides are extremely old and heavily eroded. This lack of surface evidence led to many slip planes being classified as faults. This confusion, however, is seen to be understandable due to the fact that none of the more questionable areas had been excavated sufficiently to prove their origin.

GEOLOGICAL CONSIDERATIONS

The causes of landslides are related to the physical and chemical properties of soil materials and their geological setting. The foremost often cited factors affecting slope stability are: (1) the height and angle of the slope; (2) the strength of the parent material; (3) plains of weakness such as faults and joints; and (4) water content.

The City of Chula Vista's planning area appears to contain a unique combination of bentonite material intermingled with the geologic formation known as the San Diego Formation, which is extremely susceptible to landsliding. The presence of bentonite and other sedimentary clay deposits is directly related to susceptibility to sliding. In fact, the presence of this material may be even more critical than the steepness of the terrain. Exploratory excavations in the San Ysidro Slide have revealed that nearly horizontal major or primary slip plains have developed in one to two foot thick beds of white bentonite in the Otay Formation. Furthermore, the excavations revealed that bentonite beds, commonly found in the San Diego Formation, should be considered a major factor in landsliding.

The San Diego Formation, which is found in Southern San Diego County in its sandstone form (TSDS), will very adequately hold a slope of 1.5:1, but will erode severely if it remains unplanted. This same formation in the breccia (sharp fragments imbedded in the sandstone/bentonite matrix) (TSDB) will not hold effectively a slope of 1.5:1, while the tuffaceous part (porous rock formed from stream deposits) (TSDT) will adequately hold such.

MAN-MADE ALTERATIONS

There are basically four actions taken by man which tend to increase the instability of the slopes. Three of these actions are directly related to grading, i.e., increasing the angle of the slope by removing material from its base; raising the height of the slope above the pre-existing level; and adding fill to the face of the slope top creating additional weight. One of the forces, the saturation of the slope with water from septic tanks, gutter runoff, or diverted drainage from another part of the slope, can be mitigated through the application of sound drainage engineering.

LIQUEFACTION

This form of ground failure usually accompanies earthquakes in loose, saturated sandy soils. In fact, liquefaction can only occur if the three following factors are present: (1) shallow water table; (2) loose sand, or silt; and, (3) some form of seismic activity. When these conditions are present, vibration causes the soil to compact. If the vibration is strong enough and long enough in duration, the load of over-lying soil and buildings is transferred from the soil grains to the water between the grains. For a short time the vibrated, water saturated soil acts as a liquid, and improperly designed buildings may sink, tilt or be carried toward the unsupported side of the area.

Woodward-Gizienski, in Report #71-208 prepared for San Diego Gas and Electric Company, indicated that liquefaction will modify the net effect of an earthquake in the North Island Naval Air Station area, and thus cause much greater damage to structures than would be experienced in the absence of such a condition.

DIFFERENTIAL SETTLEMENT

This type of ground failure is most often associated with earthquake activity in areas consisting of loose to medium dense granular soils which compact and are subject to vibration. If the amount of settlement is uniform in any given structure, the amount of damage could be negligible. This, however, is normally not the case. Due to heterogeneous soil-density conditions, and the fluctuation in the frequency of vibration, considerable structural damage often results.

Settlement can occur in all granular soils, and may be triggered by other earthquake induced ground failures. In such cases, damage is much more severe than that caused simply by compaction.

SEICHES AND TSUNAMIS

While ground shaking and failures, surface rupturing, and liquefaction would probably be the main agents of destruction of any major diastrophic movement in the Chula Vista Planning Area, the danger from seiches should also be mentioned. Seiches, or the oscillations of inland bodies of water, could, in the event of a major seismic shock, occur in the Bay. These seiches could destroy marinas, boats, wharves, and littoral buildings, dykes and earthworks.

Due to the location of the Continental Shelf in the San Diego Region, there is only a remote possibility that the Chula Vista Planning Area's littoral territories and structures would suffer appreciable damage from seismically-induced tsunamis.

Mudslides and Dam Failures

Mudslides, the movement of water-saturated aggregates of rock or soil, can be a secondary source of seismic hazard. While mudslides might be associated with landslides and liquefaction, they could also occur as a result of dam failure.

The Chula Vista Planning Area has three major dams--the Sweetwater, the Upper Otay, and the Savage (Lower Otay). The failure of these dams, and the subsequent saturation of the rock beds of the Otay and Sweetwater Rivers, and the Telegraph Creek could be caused by ground rupture, ground shaking, seiches, or other geologic forces. There is no substantial evidence, however, that the well-designed dams in question constitute a high geologic risk.

The State of California is currently studying the dams within its jurisdiction, and the State Office of Emergency Services now requires that the owners of dams prepare inundation maps pertaining to their facilities, and submit such, by 1976, to local jurisdictions. The preparation and submittal of these maps will probably necessitate the amendment of many municipal and county safety and seismic safety general plan elements.

SECTION II

SUMMARY (GOALS, OBJECTIVES & STATEMENTS OF POLICY)

and

CONCLUSION

SUMMARY

Goals and General Objectives

The following goals and objectives constitute the foundation of the Seismic Safety Element of the City of Chula Vista:

1. The promotion of public safety from geologic hazards.

2. The arrangement of land use and space in a manner which is consistent with authoritative seismic safety practice.

3. The establishment of policy and guidelines upon which subsequent specific and precise programs designed to promote geologic safety can be enacted and promulgated.

4. The establishing of a long range, comprehensive, and general plan for the elimination of existing hazardous land uses and public facilities.

5. The identification and appraisal of geologic hazards within the Chula Vista Planning Area.

Statements of Policy

1. The Seismic Safety and Safety Elements of the General Plan shall constitute the long range, comprehensive, and general planning policy for the protection of the Chula Vista Planning Area from geologic and fire hazards. The Seismic Safety Element shall be the principal plan with respect to geologic hazards; the Safety Element shall be predominant with respect to fire hazards.

2. The Seismic Safety and Safety Elements shall be administered and implemented as complementary plans.

3. All known, major geologic hazards shall be graphically represented on the plan diagrams of the Seismic Safety and Safety Elements, and shall be appraised and evaluated in the text of the former. As the science of seismology advances, the said diagrams and text shall be reviewed and essential revisions thereto shall be prepared.

4. The Planning Department of the City of Chula Vista is charged with the duty of keeping the Seismic Safety Element current with new geologic findings within the Chula Vista Planning Area.

5. The seismic safety program of the City of Chula Vista shall be coordinated with the seismic safety programs of the Comprehensive Planning Organization, the County of San Diego, and the several cities therein.

6. No lands shall be subdivided, developed, or filled within the City of Chula Vista in the absence of supportable, professional evidence that the proposed subdivision, development, or land fill would be geologically safe.

7. Wherever feasible, land uses and buildings which are determined to be unsafe from geologic hazards shall be discontinued, removed, or relocated.

8. The Uniform Building Code, the Fire Code, the Uniform Code for the Abatement of Dangerous Buildings, the Subdivision Ordinance, the Zoning Ordinance, and the Emergency Plans of the City of Chula Vista and the Univied San Diego Emergency Services Organization shall effectuate the Seismic Safety Element. These specific and precise plans shall be amended when their amendment is required to effectively implement this element.

9. The City of Chula Vista recognizes that its planning area is traversed by several faults, and that some geologic risks cannot be avoided without disproportionate public expenditures. Chula Vista therefore accepts minor property damage as the level of acceptable risk. The loss of life and major property damage are not acceptable risks, and shall be precluded through the stringent enforcement of local ordinances and the establishment of high priorities for public safety oriented capital expenditures.

10. Since damages can often be prevented or mitigated by effective governmental and emergency services, emergency facilities, public buildings, and communication and transportation centers should not be established in close proximity to fault traces.

11. The City of Chula Vista should initiate a public information program on geologic hazards and safety. This program should be augmented by a technical, in-service program for municipal staff.

12. When a development or subdivision is proposed in an area of known geologic hazards, the developer or subdivider shall submit a report prepared by an engineering geologist to the Environmental Review Committee.

13. Eventually, the seismic safety program of the City of Chula Vista should be based upon special land regulations and special land management zones, such as "seismic hazards management zones." The enactment of these regulations, and the establishment of "seismic hazards management zones" will require additional general and local geologic information and the synthesis of seismic safety matrices.

14. All amendments to the Seismic Safety Element shall be responsive to the California Council on Intergovernmental Relations' General Plan Guidelines, dated September, 1973, and amendments thereto.

15. The Environmental Review Committee shall annually review the Seismic Safety Element and shall report its findings to the Planning Commission of the City of Chula Vista.

Conclusion

The Seismic Safey Element constitutes the City of Chula Vista's long range, comprehensive, and general policy for the protection of its planning area from geologic hazards. The element embodies an identification of known and potential geologic hazards, and an evaluation of their effect upon people and property of this subregion. The element should be recognized as an initial plan which will be augmented in the future to reflect the growth of the science of seismology, and the City of Chula Vista's increased knowledge and understanding of local tectonic forces and geologic agents.

The Seismic Safety Element will eventually contain empirical standards and proven design proposals upon which precise land management programs can be predicated. During the present time, however, the policy of the subject element must be effectuated by this municipality's environmental review program, and its planning, building, public works, and safety codes and ordinances.

The Seismic Safety Element of the City of Chula Vista is designed to bring this city into a state of compliance with Section 65302 (f) of the State Planning and Zoning Law (Government Code). The instant element's prepration was substantially influenced by the Council on Intergovernmental Relation's General Plan Guidelines, dated September, 1973.

SECTION III

APPENDICES

Appendix A

GEOLOGIC OVERVIEW

In order to understand seismic geology, it is important that the reader be familiar with the earth, its building processes, and the vocabulary used to describe them. The earth is a spheroidal body approximately 3,960 miles in equatorial radius. The center is occupied by the core, a spherical zone 2,160 miles in radius. The core is believed to be mostly liquid surrounding a central solid portion. Outside the core lies the mantle, a layer about 1,800 miles thick, composed of mineral matter in a solid state. The outermost and thinnest of the earth's zones is the crust, a layer some 3 to 40 miles thick. The continents, oceans, and ocean basins compose the major portion of the earth's crust. However, the crust is not one continuous solid mass. It is composed of a number of plates which rest on the mantle and are subject to movement. A semi-solid zone at the interface of the earth's crust and the mantle allows for movement of the crustal plates. It is the movement of these plates into each other, away from each other, over each other, or beside each other, which accounts for the vast majority of earthquakes world-wide and all earthquakes in California.
(See Figures #2 and #3 for diagrams illustrating these concepts.)

The boundary lines between the earth's crustal plates are not always readily distinguishable on the earth's surface. Most people, when they think of surface boundaries, visualize political boundaries between nations and states or the more easily perceived physical boundaries on the earth's surface between oceans and continents. But a crustal plate may contain a number of nations, or contain oceans and continents, or a portion of both.

The fault which separates these two plates is not always perceivable on the earth's surface, but there are land forms and geologic criteria and instrumentation which can be used to map its location. The fault is not one solid, continuous line, but is composed of a system of splinter faults which appear periodically on the earth's surface. The term fault trace is used to describe a line on the surface of the earth formed by the intersection of the fault with the earth's surface.

Ground rupture and cracking are surface expressions of earthquakes which originate on subsurface faults. Earthquakes occur at various depths within the earth's crust. The point below the surface where the rupture first occurs is known as the focus and can be located with the help of seismic instruments. The news media usually use the tem "epicenter" to describe the point of initial rupture. Used in this context, the term is a misnomer. The epicenter of an earthquake is measured in two ways. The instrumental epicenter is that point on the earth's surface directly above the focus but may not be the area of maximum damage. The field epicenter is defined as the point of strongest ground shaking. The field epicenter may or may not coincide with the instrumental epicenter.
(See Figure #4 for a diagram illustrating this concept.)

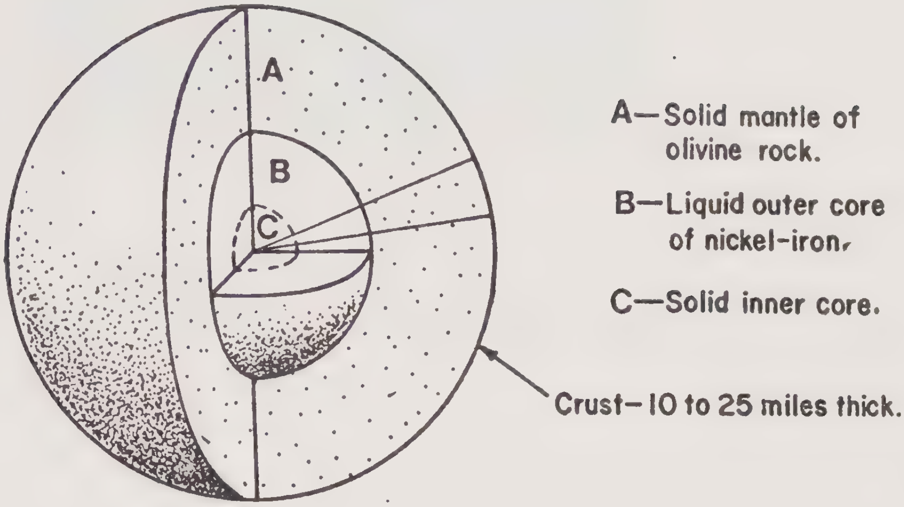

FIGURE No. 2 Diagram of Concentric Zones Which Makes up the Earth's Interior.

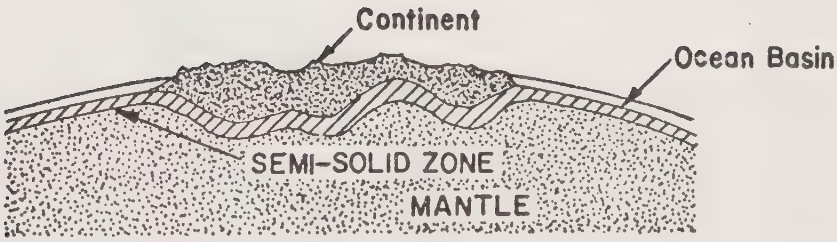

FIGURE No. 3 Cross Section of Interface Between Earth's Crust and Mantle.

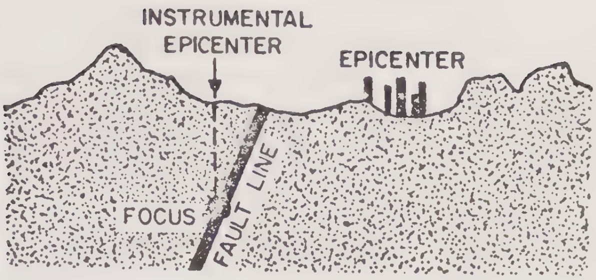

FIGURE No. 4 Visual Presentation of Different Terms Used to Describe Sources of Earthquakes and Areas of Damage.

THE CIRCUM—PACIFIC SEISMIC BELT

The mechanics of these tectonic movements involve a very slow stress-building movement within the earth's crust, normally along an existing earthquake fault. The stress in the crust is a result of crustal block movement. The resultant tectonic movement is a product of the stress release between the two opposing plates. At the present time, it is believed that there are two kind of faults: (1) active faults which have experienced displacement in recent geologic time, suggesting that future displacement can be expected on these faults; and (2) inactive faults that have shown no evidence of movement in recent geologic time, suggesting that these faults are dormant. However, some faults labeled as inactive are so termed due to lack of experimentation and research. Increased research and monitoring of these faults may expose them as active.

All fault movements are not the same. From the blocks in Figure #5, we get a visual representation of the various types of faulting which can occur along an earthquake fault. In Diagram (a) we see a symbolic representation of a section of land prior to faulting. Diagram (b) illustrates vertical faulting in the normal manner. Diagram (c) is vertical faulting but this time in reverse, usually termed a fault thrust, where the hanging wall has moved up relative to the foot wall. Diagram (d) is a lateral fault, sometimes called a slip fault, where the rocks on either side of the fault have moved sideways in relation to each other. Diagram (e) is an example of right lateral reverse fault. Movement is right lateral when the rocks on the opposite side of a fault move to the right, as observed while facing the fault; left lateral is when movement is to the left.

Earthquakes are not all the same. They can range from a minor disturbance to a catastrophic event. How then can we tell the difference between quakes and compare them to each other: The first attempt to classify earthquakes involved a description of their intensity. The scale used to measure the intensity of a quake is the Modified Mercalli Scale with intensities ranging from I to XII.
(See Figure #6 for the Modified Mercalli Scale with written descriptions of observations.)

Intensity is a description of the physical effects of earthquakes. The lowest intensity ratings are based on human reactions, such as "felt indoors by few." The highest intensities are measured by geologic effects, such as "broad fissures in wet ground, numerous and extensive landslides, and major surface faulting." The middle intensity range is based largely on the degree of damage to buildings and other man-made structures. Intensity ratings are based on visual observation and are not measured with instruments. The degree of intensity varies from place to place during an earthquake. Specific locations in an area may have an intensity rating of VIII because of soil conditions and type of building structure, while other locations affected by the same earthquake may only have an intensity of IV. Therefore, a single earthquake can have different intensity ratings based on geologic conditions, structural design, or distance from field epicenter.

In 1932, Charles Richter developed a system of tables and charts to deduce from seismological instruments a method of measuring the magnitude of an

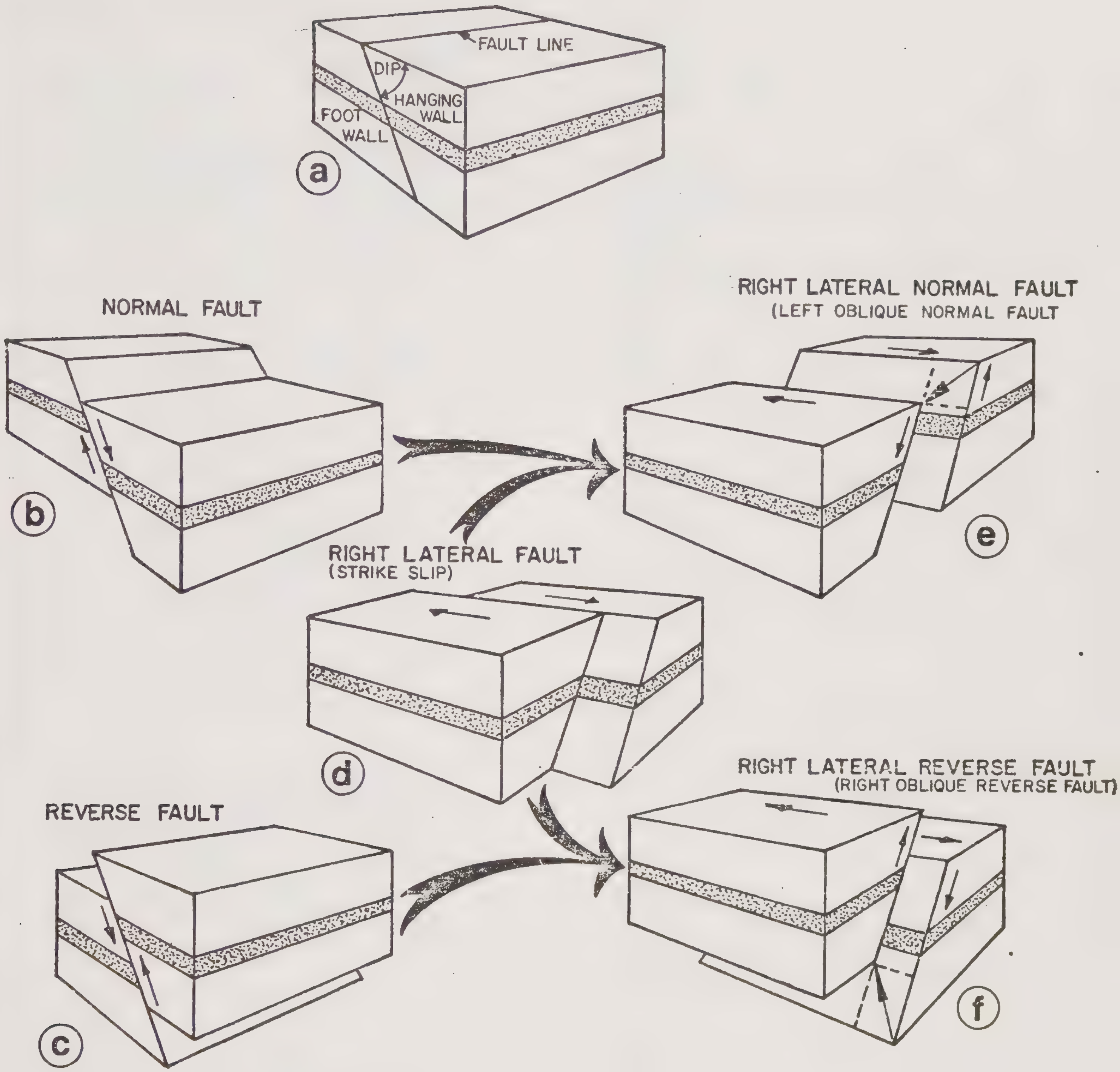

FIGURE No. 5. EXAMPLES OF VARIOUS TYPES OF FAULTING.

Figure No. 6 Modified Mercalli scale of earthquake intensities.

THE MERCALLI INTENSITY SCALE

(As modified by Charles F. Richter in 1956 and rearranged)

If most of these effects are observed	*then the intensity is:*
Earthquake shaking not felt. But people may observe marginal effects of large distance earthquakes without identifying these effects as earthquake-caused. Among them: trees, structures, liquids, bodies of water sway slowly, or doors swing slowly.	*I*
Effect on people: Shaking felt by those at rest, especially if they are indoors, and by those on upper floors.	*II*
Effect on people: Felt by most people indoors. Some can estimate duration of shaking. But many may not recognize shaking of building as caused by an earthquake; the shaking is like that caused by the passing of light trucks.	*III*
Other effects: Hanging objects swing. *Structural effects:* Windows or doors rattle. Wooden walls and frames creak.	*IV*
Effect on people: Felt by everyone indoors. Many estimate duration of shaking. But they still may not recognize it as caused by an earthquake. The shaking is like that caused by the passing of heavy trucks, though sometimes, instead, people may feel the sensation of a jolt, as if a heavy ball had struck the walls. *Other effects:* Hanging objects swing. Standing autos rock. Crockery clashes, dishes rattle or glasses clink. *Structural effects:* Doors close, open or swing. Windows rattle.	*V*
Effect on people: Felt by everyone indoors and by most people outdoors. Many now estimate not only the duration of shaking but also its direction and have no doubt as to its cause. Sleepers wakened. *Other effects:* Hanging objects swing. Shutters or pictures move. Pendulum clocks stop, start or change rate. Standing autos rock. Crockery clashes, dishes rattle or glasses clink. Liquids disturbed, some spilled. Small unstable objects displaced or upset. *Structural effects:* Weak plaster and Masonry D* crack. Windows break. Doors close, open or swing.	*VI*
Effect on people: Felt by everyone. Many are frightened and run outdoors. People walk unsteadily. *Other effects:* Small church or school bells ring. Pictures thrown off walls, knicknacks and books off shelves. Dishes or glasses broken. Furniture moved or overturned. Trees, bushes shaken visibly, or heard to rustle. *Structural effects:* Masonry D* damaged; some cracks in Masonry C*. Weak chimneys break at roof line. Plaster, loose bricks, stones, tiles, cornices, unbraced parapets and architectural ornaments fall. Concrete irrigation ditches damaged.	*VII*
Effect on people: Difficult to stand. Shaking noticed by auto drivers. *Other effects:* Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Furniture broken. Hanging objects quiver. *Structural effects:* Masonry D* heavily damaged; Masonry C* damaged, partially collapses in some cases; some damage to Masonry B*; none to Masonry A*. Stucco and some masonry walls fall. Chimneys, factory stacks, monuments, towers, elevated tanks twist or fall. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off.	*VIII*
Effect on people: General fright. People thrown to ground. *Other effects:* Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes. Steering of autos affected. Branches broken from trees. *Structural effects:* Masonry D* destroyed; Masonry C* heavily damaged, sometimes with complete collapse; Masonry B* is seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted off foundations. Frames racked. Reservoirs seriously damaged. Underground pipes broken.	*IX*
Effect on people: General Panic. *Other effects:* Conspicuous cracks in ground. In areas of soft ground, sand is ejected through holes and piles up into a small crater, and, in muddy areas, water fountains are formed. *Structural effects:* Most masonry and frame structures destroyed along with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes and embankments. Railroads bent slightly.	*X*
Effect on people: General panic. *Other effects:* Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. *Structural effects:* General destruction of buildings. Underground pipelines completely out of service. Railroads bent greatly.	*XI*
Effect on people: General panic. *Other effects:* Same as for Intensity X. *Structural effects:* Damage nearly total, the ultimate catastrophe. *Other effects:* Large rock masses displaced. Lines of sight and level distorted. Objects thrown into air.	*XII*

* Masonry A: Good workmanship and mortar, reinforced, designed to resist lateral forces.
Masonry B: Good workmanship and mortar, reinforced.
Masonry C: Good workmanship and mortar, unreinforced.
Masonry D: Poor workmanship and mortar and weak materials, like adobe.

earthquake. The magnitude assigns a number to the calculated energy release; this system can rank earthquakes and compare them to one another. By this method, an earthquake is rated independently of the place of observation.

The magnitude is the logarithm (base 10) of the maximum amplitude of a seismogram referred to a distance of 62 miles from the epicenter. Under this system, an increase of one degree in magnitude is equal to 32 times the energy of magnitude 7 and, therefore, about 1000 times the energy of magnitude 6. The common belief is that a 9.0 earthquake is only four times as great as a 5.0 earthquake. Actually an energy release of 9.0 magnitude earthquake is one million times stronger than a 5.0 earthquake. There is a tremendous increase in energy release as the magnitude is increased to the point of a great earthquake (7.0 and higher). The most vigorous earthquakes recorded by seismographs were the 1906 earthquake off the coast of South America and the 1933 earthquake off the coast of Japan, both of which had magnitude readings of 8.9. Neither earthquake was a catastrophe since both struck where there were no cities to be leveled or people to be injured.

EARTHQUAKE RELATED DAMAGE

Crustal movement and faulting are evolutionary processes in the earth's geologic history. These geologic processes have a direct impact on man and his activities when they occur in an urbanized area. Therefore, an understanding of the different types of seismic expression and their effect on development is necessary for an effective program of seismic risk reduction.

GROUND SHAKING

The stress release of an earthquake is expressed in a number of ways on the earth's crustal surface. The most common expression of earthquakes is ground shaking. Ground shaking is a result of surface wave movement through the rock materials of the outer earth's crust. The ground motion created by these seismic waves is not constant. Its direction and velocity are directly related to the geologic configuration of the earth's crustal material. Also surface topography can cause compounding of ground waves which result in concentrations of energy. As ground waves pass from rock to less dense material (alluvial or water-saturated rocks), they reduce velocity and generally increase amplitude. The more compacted material tends to filter out high frequency motion. The result is accentuated shaking on the surface for a longer period of time and at a longer period of vibration.

Therefore, proximity to the fault and/or area of initial subsurface rupture does not necessarily determine the intensity and duration of ground shaking that a building should be constructed to withstand. The type, configuration, depth, and density of the underlying soil and rock upon which a building is constructed will determine the maximum vibrational forces the overriding structure should be built to withstand.

For example, two buildings constructed beside each other on different configurations of soil and rock will be subjected to different magnitudes of vibrational forces even though they are equidistant from the epicenter of the

earthquake. Extreme examples of the different reaction to ground waves by subsurface rock strata were noted after earthquakes in Venezuela and Mexico. In Caracas, Venezuela, a high-rise building which was constructed adjacent to a masonry, colonial type structure reacted differently to ground shaking. The modern high-rise structure collapsed while the other remained standing. Likewise, an earthquake originating off the western coast of Mexico in the Pacific Ocean did little damage to the cities located between the coast and Mexico City. However, in Mexico City there was extensive damage from the offshore earthquake. Therefore, the degree of ground shaking is not entirely related to proximity of the fault or epicenter but is also dependent on the composition of underlying geologic strata.

Ground shaking is not constant. Numerous locations within a city will be subjected to various degrees of ground shaking. The strongest intensity ratings and greatest amount of structural damage should be expected in those areas where geologic conditions prolong and accelerate the amplitude of seismic waves. Because of the nature of wave movement, a structure built next to a fault on solid ground might withstand ground shaking better than a building built on loosely compacted, water-saturated material 200 miles or more away. Therefore, structures located a good distance from the fault can be a greater hazard than those located within the fault zone.

Damage from earthquake ground motion (shaking) is caused by the transmission of earthquake vibrations from the ground into the building structures. The resultant damage is related to the structural design, type of construction, and the intensity, period, and duration of ground motion. Buildings should be constructed to undergo severe shaking with minimal structural damage from vibrational forces and without collapsing. Buildings should also have systems (lighting, stairwells, communication, etc.) designed to remain functional under seismic conditions. The end result might be some structural damage but not loss of life.

GROUND RUPTURE

As earthquakes increase in magnitude (Richter Scale 1-10), there is a strong possibility of ground rupture. Ruptures usually occur on existing faults or fault traces, but rupture is possible anywhere within the fault zone, and possibly anywhere within the entire region. The rupture begins at the focus and may extend to the earth's surface. As mentioned, the point of penetration at the surface is unpredictable, although there is a very strong probability it will occur in an area of previous ground rupture.

Just as it is impossible to predict the location of ground rupture all of the time, it is also impossible to predict if faulting will be horizontal, vertical, or oblique. However, it is possible to predict that any structure located at the point of surface rupture or faulting will experience immediate destruction of foundation, with a strong probability of collapse or major damage.

GROUND FAILURE

Two other geologic processes which can result from an earthquake are landslides and liquefaction. Seismically induced landslides can be catastrophic, particularly if the earthquake occurs during or following a period of heavy rainfall. The potential for landslides exists in an area of ancestral landslides and/or areas of unstable slopes. This is especially true where the slopes have been materially modified from their natural state. Landslides can be man-induced as a result of improper grading.

Liquefaction is generally associated with intense and prolonged ground shaking. The phenomenon occurs in loose or medium-dense, water-saturated, cohesionless materials which tend to subside and flow when subjected to earthquake vibrations. As the material tends to compact, the water pressure in the soil increases and it may reach the point where it becomes equal to the overburden pressure. At this point the soil loses its strength and liquefies. In addition, there may be a transfer of water from the lower to upper levels, involving a quick or liquid condition near the ground surface. Buildings located over this type of soil will sink and/or tilt, and lighter materials, such as water and gas lines, will rise to the surface.

TECTONIC CREEP

Another common seismic expression which occurs along a fault is tectonic creep. Creep is a slight, continuous movement along a fault and is usually not accompanied by felt earthquakes. Movement is usually in the range of fractions of an inch a year. Displacement is usually lateral and may eventually destroy the foundation and bearing walls of structures built directly over the fault. This process, over a period of years, may be sufficient to cause extensive damage to structures located astride the fault.

EARTHQUAKE PREDICTION

Earthquake prediction is still in its very crude stages, and there are probably as many theories about the possible location, magnitude, and time of the next quake as there are men studying them. However, we can be sure of one thing; earthquakes will continue to occur. Although it is impossible to make precise earthquake predictions, it is possible to make some general earthquake projections. Earthquake prediction has three parameters. They are location, magnitude, and time. It is presently impossible to predict the exact location of the next earthquake. However, geologic surveys and recordings of seismic activity over the years have resulted in the identification of a global strip, entitled the Circu-Pacific Seismic Belt, where 80% of the world's earthquakes occur.

Since California is located within this major earthquake belt, and earthquake frequency is greatest on the State's historically most active faults, it can be predicted that earthquakes will occur on these California faults. Faults which have been the source of great earthquakes (7.0 or greater on the Richter Scale) in the past can be expected to have earthquakes of the same magnitude in the future. As far as the time of the next quake, it can only be said that this is an extremely active seismic area. Therefore, earthquakes in California will continue to occur in the foreseeable future.

Appendix B

CASE STUDIES OF HISTORIC EARTHQUAKES

Earthquakes are a common occurrence on the west coast of the United States. In fact, in California alone there have been seven earthquakes recorded with a magnitude of 7.0 or higher since 1857. The highest earthquake ever recorded in the State was the 1906 San Francisco earthquake with an estimated magnitude of 8.3. Accounts of the effects of the earthquake on San Francisco have been rather sketchy and most of the damage has been attributed to the fire which followed the quake. The quake claimed 700 to 800 lives.

What then can be expected in an earthquake with a magnitude of 8.0 or higher? On March 27, 1964, the City of Anchorage, Alaska, experienced an earthquake with a recorded magnitude of 8.4 on the Richter Scale. This earthquake was the first recorded earthquake to have affected water levels in wells, aquifers, and rivers all over the world. Fluctuation in water levels was recorded in 700 wells in Africa, Asia, Australia, Europe and North America. The earthquake triggered some 51 avalanches, the largest involving 1300 cubic yards of rock. The land level was altered in an area of about 70,000 square miles in south-central Alaska. Between 23,000 and 35,000 square miles were displaced as much as 33 feet. The subsea extent of land movement is not precisely known, but elevation changes as much as 49 feet have been measured. The earthquake claimed 125 lives (one in a thousand) and 300 million dollars in initial damages.

The first earthquake which had a direct impact on the improvement in structural design criteria in seismic areas was the 1933 Long Beach, California earthquake. This earthquake had a magnitude of 6.3 on the Richter Scale, resulted in 102 deaths, and caused property damage approaching 40 million dollars. If buildings in the area had been previously constructed to withstand an earthquake, the loss of life might have been much less and property damage reduced significantly. There was particular evidence in that earthquake that deaths resulted from people running out of buildings and being struck by parapets and walls of unreinforced masonry which collapsed. The Long Beach earthquake resulted in the enactment of minimum seismic design requirements which have been incorporated into the Uniform Building Code.

The February 9, 1971, San Fernando Valley, California earthquake was the most documented earthquake in history, particularly with respect to ground movement and response of structures to such motion. This earthquake has provided significant data on how structures reacted to ground shaking under different geologic and soil conditions. The earthquake had a magnitude of 6.6 on the Richter Scale, but the intensities observed were far greater than those expected from an earthquake of this magnitude. The extreme intensities observed were found to be related to soil conditions and to building design and construction. The buildings in the area of greatest damage are underlaid by various thicknesses of recent alluvial deposits. Damage in the San Fernando earthquake was also caused by ground rupture beneath structures. Ground rupture can result from the initial energy release at the focus and/or ground shaking in an area of loose alluvial deposits. Ground rupture most likely will occur in areas of past rupture. These areas are identified by existing fault ruptures and fault traces.

The structures in the San Fernando Valley were predominantly single family, single story, wood frame dwellings, which are relatively safe under seismic conditions. Of the 65 reported deaths due to the quake, only four involved buildings constructed after 1933. There was also some damage to buildings in downtown Los Angeles. Generally speaking, the buildings most likely to fail during an earthquake are those constructed of unreinforced masonry and concrete. Unreinforced masonry, parapets, and appendages are particularly prone to failure. Ornamental appendages and inadequate wall anchorages to floors and roofs constitute additional earthquake hazards. As a result, the problem facing most cities does not only involve the control of future development, but the reduction of the hazards built into past development.

Appendix C

GLOSSARY

Alluvium - A general term for the sedimentary material deposited during comparatively recent geologic time by a stream or other body of running water in the bed of a stream or on its flood plain delta.

Ambient (Air) - Surrounding on all sides, encompassing.

Basement - The crust of the Earth below sedimentary deposits.

Batholith - A great mass of intruded igneous rock that for the most part stopped in its rise a considerable distance below the surface.

Beach - The zone of unconsolidated material extending landward from the mean low water line to the place where there is a change in material or physiographic form as, for example, the zone of permanent vegetation, or a zone of dunes, or a sea cliff.

Beach Face - The sloping section of the beach below the berm normally exposed to the wave uprush.

Beds - Layers in sedimentary rocks, distinguished from one another on the basis of rock type, grain size, composition, color, etc.

Bedrock - Rocks of various types that form the earth's crust and underlie loose surficial materials including soils.

Bentonite - A clay formed by the decomposition of volcanic ash having the ability to absorb large quantities of water and to expand to several times its normal volume.

Clast - Fragment of metamorphosed rock.

Coastal Zone - The area from the edge of the continental shelf to the foot of the coastal mountain range.

Compressible Soil - A soil susceptible to compaction under weight or pressure.

Conglomerate - A coarse-grained sedimentary rock composed of rounded fragments larger than 2mm in diameter set in a fine-grained matrix of sand, silt, or any of the common natural cementing materials.

Country Rock - Lithified or consolidated older material below the soil horizon, beach sand, etc.

Cretaceous - A period in geologic time, approximately one hundred million years ago and the corresponding system of rocks laid down at that time.

Crust - The outermost zone of the earth, composed of solid rock between and miles thick.

Diastrophism - The action of forces which cause the earth's crust to be deformed, producing continents, mountains, changes of level, etc.

Earthquake - Perceptible trembling to violent shaking of the ground, produced by sudden displacement of rocks below the earth's surface.

Epicenter - The point on the earth's surface directly above the point of origin of an earthquake.

Equilibrium - In geology, a balance between form and process.

Erosion - The process whereby earth materials are loosened, worn away, decomposed, dissolved and transported from one place to another.

Expansive Soil - A soil susceptible to expansion in the presence of moisture.

Fault - A fracture in the earth's crust along which there has been movement of the two sides relative to one another.

Fault Creep - Slow, continuous or spasmodic displacement along a fault.

Fault Scarp - A cliff formed by displacement along a fault.

Fault Trace - A lineation on the earth's surface marking the intersection of a fault with the earth's surface.

Fault Zone - An area consisting of a series of generally subparallel, locally branching, closely spaced faults and fault traces.

Faulting - The movement which produces relative displacement of adjacent rock masses along a fracture.

Fissure - An extensive crack, break, or fracture in the rocks.

Fold - A bend in formerly horizontal rock layers.

Fracture - Break in rocks due to intense folding or faulting.

Geology - The science which treats of the earth, the rocks of which it is composed, and the changes which it has undergone or is undergoing.

Geotechnical - Pertaining to geology-soils-engineering studies, features, conditions or events.

Granitic Rock - A term loosely applied to any light-colored, coarse-grained plutonic rock containing quartz as an essential component, along with feldspars and mafic minerals.

Ground Rupture - A break or fracture of the earth's surface along a fault; the primary effect of earthquakes; also called surface faulting.

Hiatus - A lapse in continuity as in the sequence of sedimentary rock.

Holocene - The present geologic epoch of the Quaternary Period of the Cenozoic Era.

Igneous - The class of rocks formed by cooling and crystallization from a molten state.

Inversion - In climatology, a layer of warm air aloft containing cooler air below and preventing the upward escape of airborne particles in the cool air layer.

Isoseismic Line - An imaginary line connecting all points on the surface of the earth where an earthquake shock is of the same intensity.

Joint - A surface of actual or potential fracture or parting in a rock, without displacement.

Lateral Spreading - The movement of loose soils over low-angle slopes into open areas, due to ground shaking during an earthquake.

Liquefaction - A "quick" condition generally created in certain types of saturated soils during earthquake shaking.

Lithosphere - The solid portion of the Earth including the crust and uppermost mantle.

Littoral - Relating to the seashore or coastal region.

Low Pressure - In climatoloty, a trough of air weighing less heavily on the surface of the earth usually accompanied by upward motion of air and some precipitation.

Lurch Cracking - The development of all types and sizes of fissures in the ground due to ground motion during an earthquake.

Magma - Naturally occurring mobile rock material, generated within the Earth and capable of intrusion and extrusion, from which igneous rocks are thought to have been derived through solidification and related processes.

Magnitude - A quantitative measure of the total energy released by an earthquake, according to the Richter Scale. Earthquakes assigned Richter Scale numbers up to 5 are classified as minor, those from 5 to 7 are classified as moderate, those above 7 are classified as major.

Mantle - The zone of the Earth below the crust and above the core.

Metamorphic - The class of rocks which have been transformed from their previous state by heat or pressure or both.

Metavolcanic - Pertaining to rock, volcanic in origin, that has been changed or metamorphosed by subsequent influences.

Microclimate - Essentially uniform local climate of a small site.

Mud Flow - A flowage of heterogenous debris lubricated with a large amount of water, usually following a former stream course.

Plate (geol.) - One of the large, nearly rigid, but still mobile segments or thin blocks involved in plate tectonics, with a thickness that includes both crust and some part of the upper mantle.

Pleistocene - Earliest epoch of the Quaternary Period of the Cenozoic Era; about 3,000,000 years ago.

Pliocene - The latest epoch of the Tertiary Period occurring within the last few millions of years and the corresponding system of rocks laid down at that time.

Pocket Beach - A short, isolated beach characterized by the presence of a shallow veneer of sand over rock.

Quaternary - Most recent geologic period of the Canozoic Era; the present period.

Residual Soil - Soils formed in place on bedrock by the disintegration and decomposition of the rock.

Richter Scale - The range of numerical values of earthquake magnitude. Very small earthquakes can have negative magnitude values. The strength of Earth materials produces an upper limit of slightly less than 9.

Rock Type - The basic unit in classifying rocks according to their geologic history, composition, grain size, texture, hardness, color, etc. Some of the rock types referred to in this report are chert, conglomerate, rhyolite, sandstone, serpentine, shale and siltstone.

Sandstone - A sedimentary rock formed by the cementation of individual grains of sand size and commonly composed of the mineral quartz.

Santa Ana - Hot, dry east wind generated from high pressure system in interior of continent.

Scarp (beach) - An almost vertical slope along a beach.

Sediment - Material deposited by water or wind, the components of sedimentary rock.

Sedimentary - The class of rocks formed by the hardening of accumulated layers of sediments such as sands and clays.

Seiche - An earthquake-generated wave within an enclosed or restricted body of water such as a lake, reservoir, or lagoon.

Seismic - Pertaining to, characteristic of, or produced by earthquakes or earth vibration, as, seismic disturbance.

Settlement - The downward movement of soil, and structures on or in it, resulting from reduction in the voids in the underlying soil.

Shale - A fine grained sedimentary rock made up of silt and clay-sized particles.

Shear - A kind of fracture in rock produced by intense pressure.

Shear Zone - An area in which shearing has occurred on a large scale.

Soil Type - The basic unit in classifying soils according to their geologic history, grain size, texture, composition, etc. Some of the soil types referred to in this report are silts, clays and sands.

Spring Tide - Tide of greater-than-average range around the times of new and full moon.

Stratum - The section of a formation that consists throughout of approximately the same kind of rock material, and may consist of an indefinite number of beds or layers.

Subsidence - A local mass movement that involves the gradual downward settling or sinking of the Earth's surface with little or no horizontal motion and that does not occur along a free surface.

Syncline - A downfold in layered rock, resembling a trough.

Tectonic Movement - The movement caused by an earthquake which results in deformation of the Earth's crust.

Tectonics - A branch of geology dealing with the broad architecture of the upper part of the Earth's crust, that is, the regional assembling of structural or deformational features, a study of their mutual relations, their origin, and their historical evolution.

Thermocline - The zone where temperature changes rapidly with depth.

Tsunami - (Pronounced Soo-nom-ee) A great sea wave produced by submarine earth movement or volcanic eruption.

Uplands - Lands above tidelands, on the landward side of an established line; in the case of San Diego Bay, the Mean High Tide Line of 1918.

Vibrational Damage - Damage to a structure caused by the transmission of earthquake vibrations from the ground into the structure.

Weathering - Disintegration, decomposition, and dissolving of earth materials at or near the surface.

Appendix D

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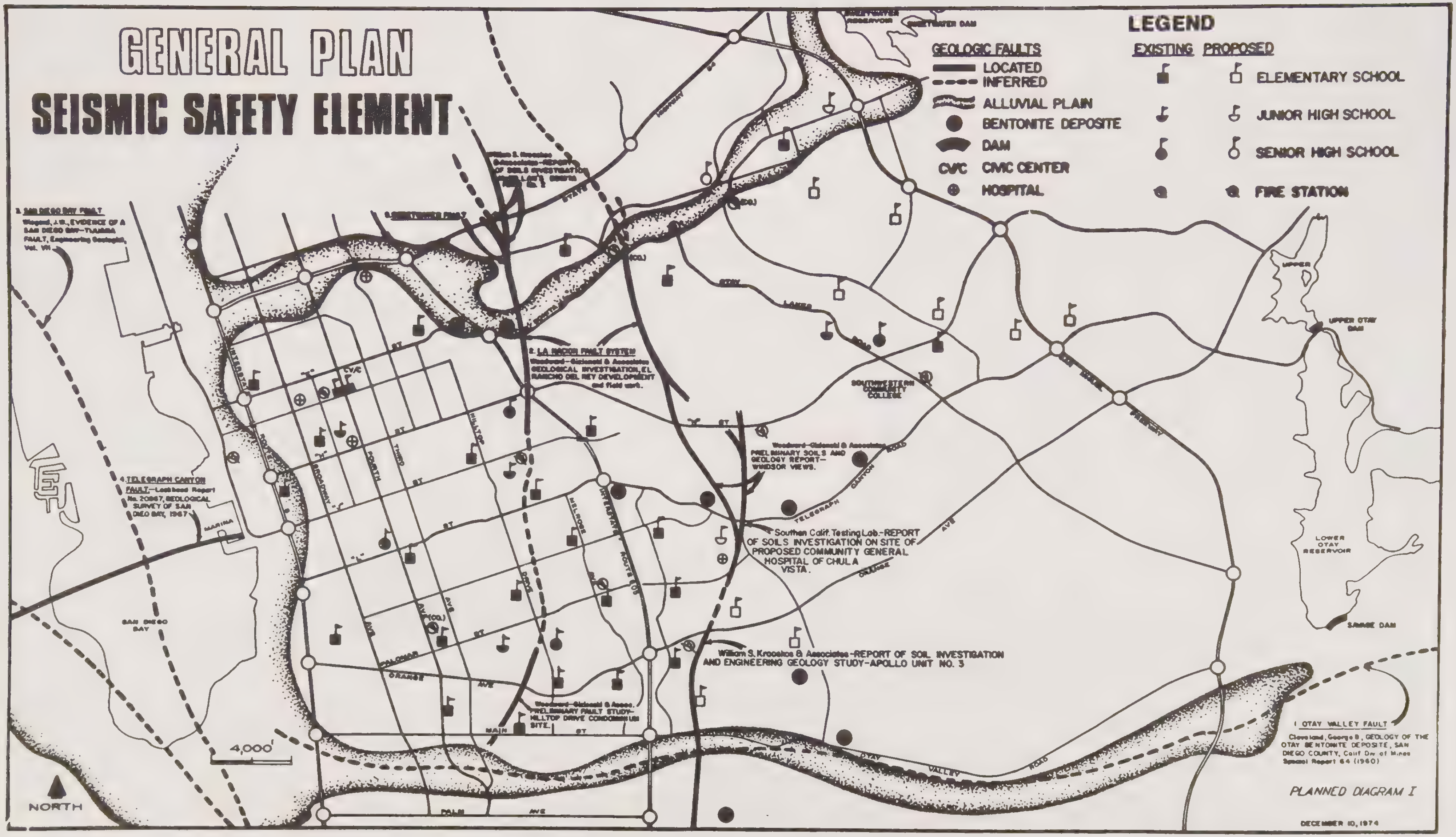
SECTION IV

PLAN DIAGRAM



GENERAL PLAN
SEISMIC SAFETY ELEMENT
LEGEND
GEOLOGIC FAULTS
LOCATED
INFERRED
ALLUVIAL PLAIN
BENTONITE DEPOSITE
DAM
CV/C CIVIC CENTER
HOSPITAL
EXISTING PROPOSED
ELEMENTARY SCHOOL
JUNIOR HIGH SCHOOL
SENIOR HIGH SCHOOL
FIRE STATION
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MARINA
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TELEGRAPH CANYON ROAD
ORANGE AVE
MAIN ST
PALM AVE
OTAY VALLEY ROAD
LOWER OTAY RESERVOIR
UPPER OTAY DAM
SAVAGE DAM
1 OTAY VALLEY FAULT
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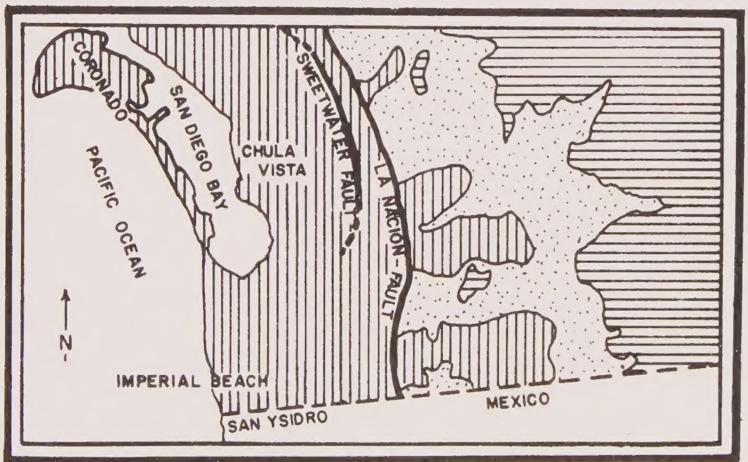
4,000'
NORTH
PLANNED DIAGRAM I
DECEMBER 10, 1974

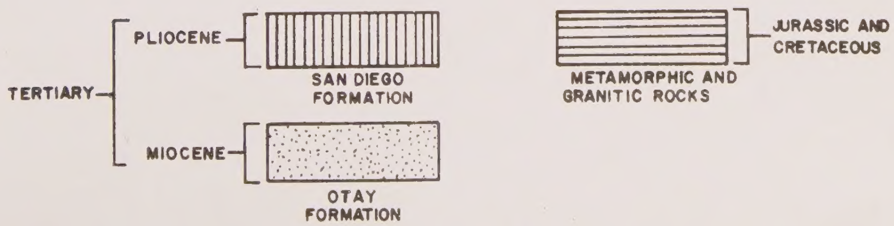
GEOLOGIC TIME SCALE

ERAS	PERIODS, EPOCH'S	TIME IN MILLION YEARS	SOME GREAT EVENTS IN CALIFORNIA	LIFE ON THE EARTH
Cenozoic	Quaternary Recent or Holocene	0.01	Continued faulting and Mountain Building	
	Pleistocene	3		
	Tertiary Pliocene	11	Principal building of Coast and Transverse Ranges	Great land mammals Oldest man
	Miocene	25	Local movements in Coast and Transverse Ranges	
	Oligocene	40		First apes
	Eocene	60	Widespread Coastal Seas	First placental mammals
	Paleocene	70		
Mesozoic	Cretaceous	135	Building of the Sierra Nevada, Klamath and Peninsular Ranges	Extinction of dinosaurs
	Jurassic	180		Age of dinosaurs
	Triassic	225	Shallow seas	First dinosaurs
Paleozoic	Permian	270	Volcanism and mountain building (extent unknown)	Rise of reptiles
	Pennsylvanian	305		
	Mississippian	350	Probably shallow seas over much of California, Cambrian to Permian	First reptiles
	Devonian	400		First land vertebrates
	Silurian	440		Fishes abundant
	Ordovician	500		Trilobites dominant
	Cambrian	600		First abundant fossils
Precambrian	Late	1800	Uplift Mountain building in Southern California	Organic tubes in marine limestone
	Early	2700	Oldest rocks and mountains	Oldest fossils (algae?) First life (?)
Crust of the earth solidified about 4,000 million years ago		4500	Origin of the earth	



GEOLOGIC FORMATION MAP

SCALE
1"=19.30 Miles



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